CLASS
CLIMATE LINKED ATLANTIC SECTOR SCIENCE

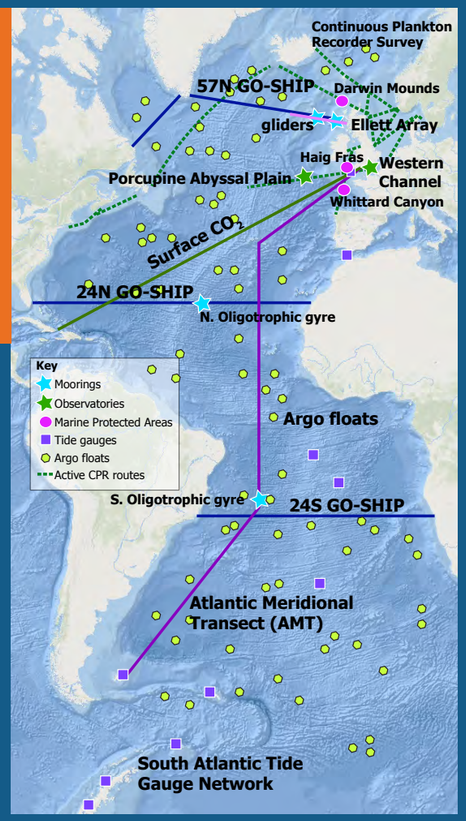
CLIMATE LINKED ATLANTIC SECTOR SCIENCE REPORT 2021

Providing an update on understanding of the science and impacts of the changing Atlantic Ocean

KEY MESSAGES & STATISTICS
2021

CLASS is a long-term, basin-scale, UK National Capability programme providing knowledge for research and societal needs, our research explains how changes in the Atlantic Ocean have profound effects on marine ecosystems and people in the UK.

The CLASS Atlantic Ocean observing system underpins world-leading research and climate and ecosystem assessments.



CLASS Atlantic observing system
CLASS data available at bodc.ac.uk

The UK Met Office ocean and climate predictive systems depend on our ocean models and data.

Through development of new sensors and platforms, CLASS is enhancing our ability to characterise the changing global ocean.

5	**UK Marine Science centres**
230	**papers published in 2018-2020, including 17 in high impact journals Nature and Science**
1500+	**citations**
800+	**times CLASS publications have been picked up by news outlets**
700+	**social media followers**
11,000+	**social media impressions per month**
10	**open ocean research expeditions leading to 260 datasets stored at BODC**
67,000+	**kilometres sailed**
~6000	**samples collected**
124	**visits to the Western Channel Observatory near Plymouth**
10,000+	**nautical miles per month sampled – Continuous Plankton Recorder**
50	**commercial ships voluntarily collecting data for CLASS**
44	**students from 18 universities took collected data and samples on CLASS expeditions**
4	**Early Career Researchers received fieldwork funding supporting their career development**
Underpinning, supporting or collaborating with:	
14	**EU-funded projects**
15	**NERC-funded projects**
6	**GOOS networks**
5	**international data hubs**
7	**societal-relevant model capabilities delivered in collaboration with the Met Office**
150+	**users from 109 organisations access the Met Office-NOC model datasets every month**
10,000+	**TB of Met Office-NOC model data downloaded every month**

Met Office

MAJOR SCIENTIFIC ADVANCES IN HOW CHANGE IN THE ATLANTIC OCEAN AFFECTS CLIMATE AND ECOSYSTEMS

Arctic precipitation and ice-melt changes Atlantic salinity

Atlantic Ocean currents are incredibly important for citizens of Northern Europe, including the UK. The Meridional Overturning Circulation (MOC) is a system of major currents that carries tropical heat to north-west Europe, keeping temperatures 3°C warmer than the same latitudes at the western margin of the Atlantic. Climate models predict a slowdown of the MOC with lower Atlantic salinity and rising global temperature. CLASS research has shown that North Atlantic salinity is sensitive to changes in winter wind patterns and the amount of precipitation and ice melt water coming from Greenland and the Arctic. Additionally, our research has shown that the region between the UK and Greenland is critical for setting the strength of the MOC, overturning previous understanding that the Labrador Sea was more important.

CLASS results are changing the ways we evaluate and improve ocean and climate models.

Fragmentation of sinking particles controls carbon sequestration

The currents of the MOC supply nutrients that sustain high levels of biological productivity in the subpolar region, leading to strong biological uptake of carbon by the ocean. CLASS analysis of biogeochemical Argo float data has revealed that fragmentation of sinking organic particles is the primary process controlling the rate of deep sequestration of carbon. By breaking into smaller clumps, the particles carry much more carbon to the seafloor than previously thought, explaining up to 50% of carbon previously unaccounted for in the global carbon budget.

Solving the mysteries of “missing” carbon in the global budget.

Six decades of change in plankton communities

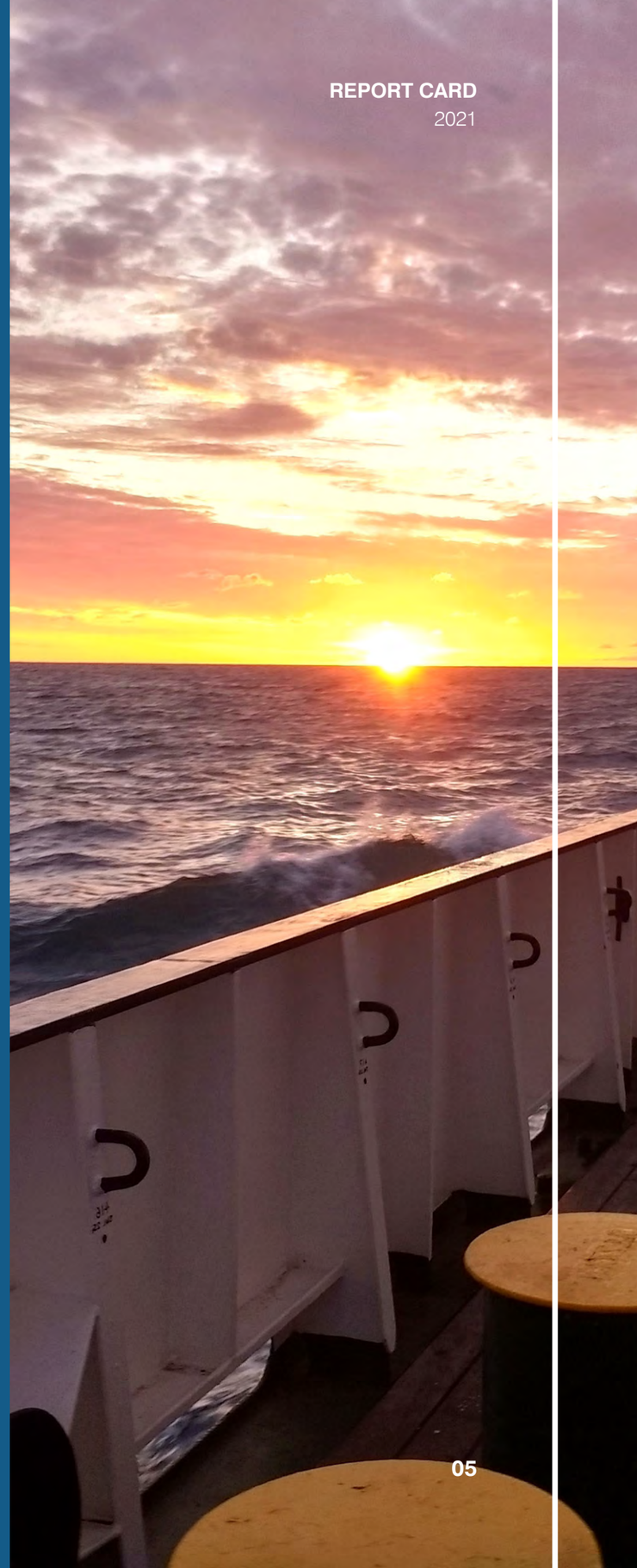
The Atlantic supports diverse biological communities in the water column and at the seafloor, and these act as biodiversity reservoirs, underpin the marine food web and supply oxygen to the atmosphere; in essence they are the ocean’s natural capital. As the environment of the Atlantic ocean changes, so the ecosystems change in response. Data from the Continuous Plankton Recorder survey has shown that over the last six decades and 7 million miles of sampling, as temperature has increased so the makeup of the plankton population found in Britain’s coastal and offshore waters has dramatically shifted. These changes have consequences for marine biodiversity, climate change (carbon cycling) and food webs including commercial fisheries.

Evidence of both the growing impacts of climate change and the mounting human pressures on ocean ecosystems.

Up to 21 million tonnes of microplastic in Atlantic, and hotspots are controlled by ocean currents

With the UK leading calls for commitment to protecting 30% of the global ocean by 2030, CLASS research is showing how seafloor communities are impacted by natural and human disturbances including landslides, fishing and plastic pollution. CLASS research has shown increasing levels of macroplastics in the oceans and revealed the highest levels of microplastic yet recorded on the seafloor, with up to 1.9 million pieces in an area of just one square metre. Deep-sea currents act as conveyor belts, transporting tiny plastic fragments and fibres across the seafloor into ‘microplastic hotspots’. CLASS has estimated that 12-21 million tonnes of tiny plastic fragments are floating in the Atlantic Ocean; a much higher amount than previously thought.

Results highlight the need for policy interventions to limit the future flow of plastics into natural environments and minimise impacts on ocean ecosystems.



PARTNERSHIPS AND LEADERSHIP FOR RESEARCH AND THE GLOBAL OCEAN OBSERVING SYSTEM

The CLASS observing system provides high quality coastal to deep ocean, surface to seafloor, physical, biological and chemical data from the Atlantic Ocean. It builds on our historic legacy of many decades of UK observations, providing unique climate time series information. It is the largest component of the UK contribution to the international Global Ocean Observing System (GOOS). GOOS provides Essential Ocean Variables for climate and environmental assessments, operational forecasting needs, and climate and earth system research. Through CLASS the UK takes a leading role in the coordination and governance of GOOS and its networks, as well as expert groups for intergovernmental organisations such as the World Meteorological Organisation (WMO), the Global Climate Observing System (GCOS) and the International Council for the Exploration of the Sea (ICES).

CLASS delivers research and knowledge through national and global partnerships with 26 different universities and 14 research centres. We work closely with UK partners such as the Joint Nature Conservancy Council (JNCC), the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), the National History Museum, the Royal Navy, and the Met Office. CLASS provides essential infrastructure for UK marine science, underpinning 12 NERC research projects, eight European Union H2020 projects, and 2 European Space Agency projects.

CLASS is a major contributor to global networks and international research, providing scientific and governance leadership as well as data, facilities and new knowledge

ENHANCING THE ACADEMIC RESEARCH ENVIRONMENT

Creating opportunities for early career researchers

CLASS places students and Early Career Researchers (ECRs) from universities around the world on our research expeditions. The ECRs are given the opportunity to develop their skills and collect new samples and data for their own research. During 2018-2020, we provided berths to 44 students from 18 different universities, supporting a very wide range of new and innovative research.

CLASS has a competitive Fellowship scheme that provides financial support for ECRs to extend their research through building on CLASS facilities and expeditions. In 2018-2020 four CLASS Fellowships were awarded to ECRs from the Universities of Bristol, Manchester and Southampton and the Flanders Marine Institute. Awards supported testing of novel sensors and platforms for monitoring coastal ocean acidification, and the study of the uptake and storage of atmospheric CO_2 in the North Atlantic. Two awards have been postponed due to Covid-19: those are for the analysis of NOC sediment cores to study transport and burial of ocean carbon in seafloor sediments, and the optimisation of a novel sensor to study the role of silicon in the growth and Atlantic phytoplankton.

In 2020 the Covid-19 pandemic forced CLASS to suspend its early career researcher schemes; instead we designed a new training scheme for developing seagoing leadership skills. From 2021 NERC research expeditions will have a Chief Scientist and co-Chief Scientist, pairing an ECR with a more experienced researcher. As part of the scheme, NERC will hold a competitive, open call for funding three ECRs to take up co-Chief Scientist positions each year.

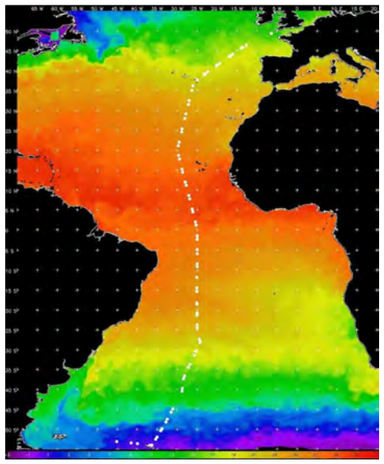
OBSERVING SYSTEM STATUS AND PROGRESS

Measurements from observatories, moorings and ships

The **Atlantic Meridional Transect** (AMT) programme has now been running for 20 years, providing annual measurements on a route between the UK and South Atlantic. During the 2018 and 2019 cruises, 118 conductivity, temperature and depth (CTD) profiles were conducted and 1000s of underway measurements recorded, covering almost 100° range in latitude. A variety of techniques, sampling and measurements were used to determine distribution, abundance and characteristics of phytoplankton, zooplankton, archaea and bacteria, including net hauls and flow cytometry measurements. This represents a fraction of the total measurements and data collected; 158 datasets from the 2018 cruise have already been submitted to the British Oceanographic Data Centre (BODC). The data collected on AMT cruises underpin important advances in our understanding of the Atlantic. For example, improved remote satellite sensing techniques resulting from comparison with AMT data, ultimately enabling measurements over larger areas and greater time periods without the need for more ships or moorings.

At the beginning of 2020, the eighth repeat of the 24˚N **GO-SHIP** hydrographic section was undertaken on a research cruise from Florida, USA to Tenerife, Spain. During the cruise, 135 full depth CTD stations were completed along the transect, with measurements and sampling for physics data, carbon, oxygen and nutrients. Data from the cruise has already been cleaned, calibrated and sent to data centres and calculations of heat, freshwater and other fluxes, as well as decadal changes are in progress. Preliminary processing has already revealed significant results in that the upper ocean part of the 24.5˚N section has become warmer, saltier and higher in carbon over the last 10 years.

CLASS supported the UK-Caribbean **SOOP** (Ships of Opportunity) route in 2018-2019. The GEEST Line route has been providing sea surface CO_2, temperature, salinity and



Route of the Atlantic Meridional Transect (AMT) shown on a map of sea surface temperature (SST)

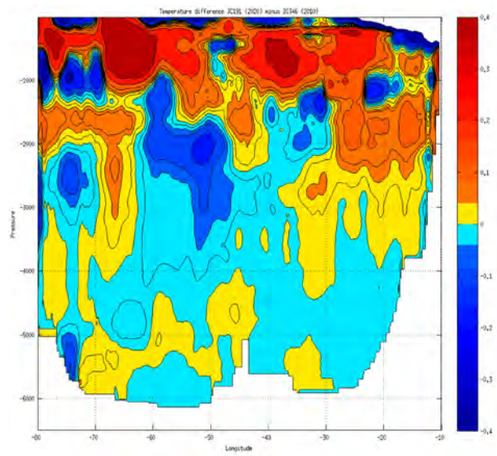
nutrient data since 2002. Recorded increases in atmospheric CO_2 are not mirrored in the sea surface CO_2, however increasing variability, particularly in winter is seen. On the UK-Falklands route, where in addition to on board sensor instrumentation, the engineers also take daily samples, five trips were made in 2018-2019 providing sea surface CO_2 data and samples for dissolved inorganic carbon (DIC) and total alkalinity (TA) measurements. Data has been used in combination with Integrated Carbon Observation System (ICOS) and Surface Ocean CO_2 Atlas (SOCAT) data to understand the processes that affect surface O_2 and CO_2

The **Continuous Plankton Recorder** (CPR) Survey towed 120,000 nm and analysed over 4000 samples in 2018-2019, continuing more than 60 years of uninterrupted monitoring in the North Atlantic. There was no break in the time series in 2020 for core regions despite the Covid-19 pandemic. With a total of 7 million nm towed and over 250,000 plankton samples, the CPR datasets are a crucial contribution to assessing biological changes in the Atlantic. The survey capabilities are being expanded beyond the existing biological measurements, such as molecular methods for harmful algal blooms (HABs) and marine pathogens. Optical methods are also being developed to speed up and compliment the normal plankton analysis along with new machine learning algorithms to speed up data analysis. Alongside traditional biological sampling, pCO_2 sensors have been tested on some CPR routes.

Weekly sampling at the **Western Channel Observatory** (WCO) was maintained throughout 2020 at both the E1 open shelf station and the L4 coastal station, thanks to the efforts of PML and MBA staff in adapting to operating during a pandemic. Sampling at E1 started in 1903, making it one of the longest oceanographic time series in existence. It provides important data to ICOS and contributes to publications such as the ICES Report on Ocean Climate.

While WCO observations in their own right provide important insights into the changing marine ecosystem, they are even more powerful when coupled with other datasets. Combining WCO data with time series from CPR survey transects and coastal/inshore sampling programmes revealed a change in the state of pelagic habitats across the North-West European shelf. Knowledge about changes in plankton communities is crucial to enable policymakers to make effective decisions regarding the management of marine ecosystems. Integration of WCO data with CPR survey data, satellite chlorophyll data and Celtic Sea sampling data has also allowed researchers to determine how nutrient stress drives food web structure. These combined datasets, alongside other UK plankton datasets are also being used in the UK Marine Strategy and, via the OSPAR Commission, in the EU Marine Framework Strategic Directive.

A major objective for CLASS are cruises to maintain the **Ellett Array** moorings; these



Difference between 2020 and 2010 temperature measurements from the GO-SHIP programme showing upper ocean warming

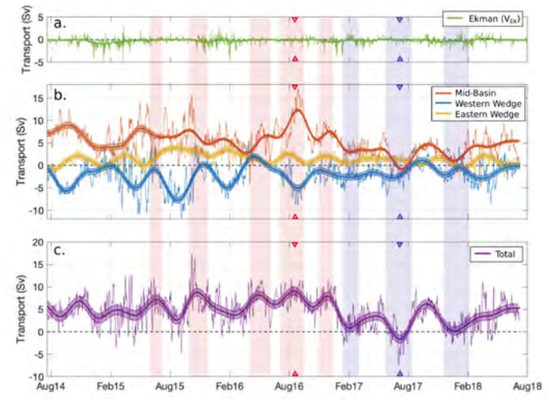
Continuous Plankton Recorder (CPR) North Atlantic Routes (historical and current)

took place successfully in July 2018 and October 2020. Continuous measurements (10-day means) of ocean volume, temperature and salinity transports through the Rockall trough were delivered. The data has been analysed and a paper on the variability of the North Atlantic current through the Rockall trough has been published, revealing a large variability in the eastern North Atlantic circulation due to changes in the North Atlantic Current. This continuous time series is also allowing new types of analysis and revealing, for example, seasonal signals with much greater significance than was previously detectable. The data has been submitted to BODC as well as provided to the OSNAP (Overturning in the Subpolar North Atlantic Program) International Data Working Group where CLASS researchers are contributing authors to forthcoming publications.

Summer and winter glider missions have been conducted, aiming to increase the spatial coverage of the Ellett Array moorings. In consultation with OSNAP, the sampling strategy has been changed to measure the shelf edge current. This is a significant pathway for Atlantic MOC transport but has proved impossible to measure using moorings due to the intensity of fishing activity. Work has focussed on determining whether gliders can accurately assess transport and on mitigating the risks of surface collision or entanglement with fishing nets.

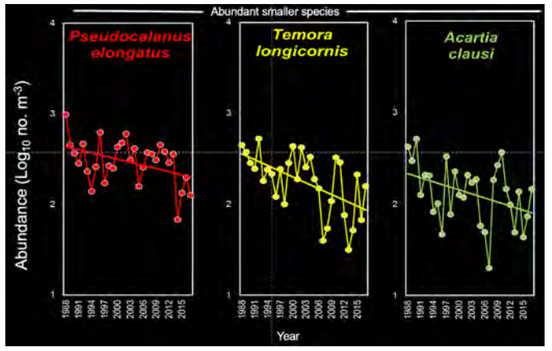
The **Porcupine Abyssal Plain Sustained Observatory** (PAP-SO) is the UK's open ocean ICOS station. The time series data for sea surface CO_2, pH, benthic biota and many other parameters has continued under CLASS, delivered through a combination of surface and subsurface instruments and sensors, deep sediment traps and seabed cameras. Major objectives for this period of CLASS were cruises in both 2018 and 2019 to service the mooring and instruments and to conduct sampling and surveys. Data from both cruises have been submitted to BODC with CO_2 related data also submitted to ICOS and SOCAT.

The combination of long term physical, biogeochemical and biological time series data from PAP provides a powerful tool in understanding the changes occurring in the Atlantic, allowing the linking of surface water, water column and deep ocean processes.



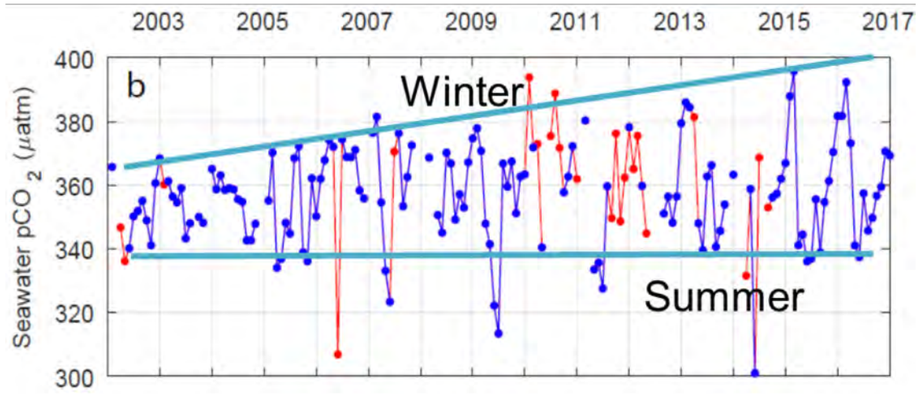
4 year time series of transport from Ellett array mooring measurements illustrating variability of the North Atlantic current in the Rockall Trough

For example, evidence of increased activity in some deep-sea deposit feeders seen via Bathysnap, a time lapse camera deployed on the seafloor, can be linked to seasonal fluctuations in phytodetritus input measured in water column sediment traps.



WCO observations showing definite shifts in abundance of different zooplankton species over time

The **South Atlantic Tidal Gauge Network** (SATGN) was established in 1985. It provides an important time series of sea level, water temperature and air pressure which is crucial to understanding sea level variability and ocean current fluctuations (particularly the Antarctic Circumpolar Current) and to enable 'ground truthing' of satellite altimetry. In addition this data allows evaluation of storm surges and tides, vital for e.g. coastal protection and port operations. Work has focused on the refurbishment of the tidal gauges to replace worn out or damaged components and upgrade sensors.

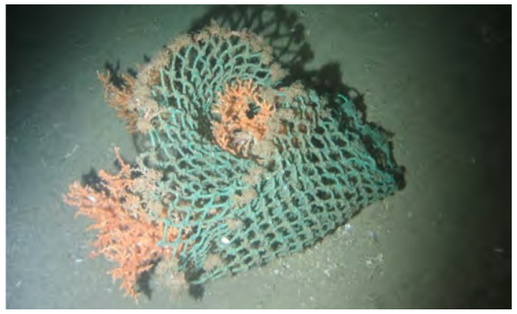


An example of a time series from PAP-SO

CLASS brings together several long term programmes to form an extensive Atlantic Ocean observing system. The combination of ship based measurements from repeat transects with data from floats and fixed instrumentation (moorings, observatories, tidal gauges) provides a comprehensive set of data for evaluating the impact of climate change on the Atlantic ecosystem. This in turn provides key evidence for policy advice related to our use and protection of the oceans.

Assessing human impact in the marine environment

A crucial tool in assessing the impact of human activity in the marine environment, and distinguishing between natural and anthropogenic influences, is the use of repeat surveys and monitoring at specific sites. The intent of CLASS in the first half of the project was to conduct fieldwork at two key sites, the Haig Fras Marine Conservation Zone (MCZ) and the Darwin Mounds.



Fishing nets snagged on corals at the Darwin mounds

Haig Fras MCZ, the only rocky reef in the Celtic Sea, was surveyed using the Autosub autonomous underwater vehicle (AUV) in 2018 to obtain acoustic (sidescan sonar) and image data. This adds to the 2012 and 2015 surveys and expanded the study of this area with a comparison of daytime and night-time benthic communities. Image analysis from these surveys has shown distinct benthic communities on different seafloor substratum. The sidescan data and machine learning techniques have been used to map where these communities occur and then show the changes of habitat over time.

The Darwin Mounds were re-mapped in 2019 (adding to the first mapping data in 1998-2000 and repeat mapping in 2011) using Autosub6000 to conduct six sidescan sonar and BioCam photography surveys. HyBIS video transects were also conducted, sediment samples collected and settlement experiments recovered. There was little change in the morphology of the mounds and no new trawl marks were discovered but there were considerable amounts of litter, especially fishing equipment. Analysis is ongoing, including a 'human vs computer' test to see whether machine learning technology or humans are quickest at estimating the amount of coral cover in images.

Whittard Canyon and the Canyons Marine Conservation Zone were due to be revisited in 2020 to conduct fieldwork and repeat surveys. The suspension of the cruise program due to Covid-19 means that this has been postponed until at least 2021. However the collaborative power of the CLASS program enabled a mooring to be deployed during one of the PAP cruises in 2019 and some work to be completed during the Haig Fras cruise. This included remotely operated vehicle (ROV) video surveys along with sampling of specimens and sediments, and AUV acoustic and image data. The mooring will also be recovered, serviced and redeployed during the next PAP cruise.

Although mapping of the Darwin Mounds did not find evidence of new coral growth, settlement experiments show that there are coral larvae in the area and therefore the potential for new cold-water coral colonies exists.

Images of benthic invertebrates and demersal fish at Haig Fras MCZ, taken by AUV mounted cameras

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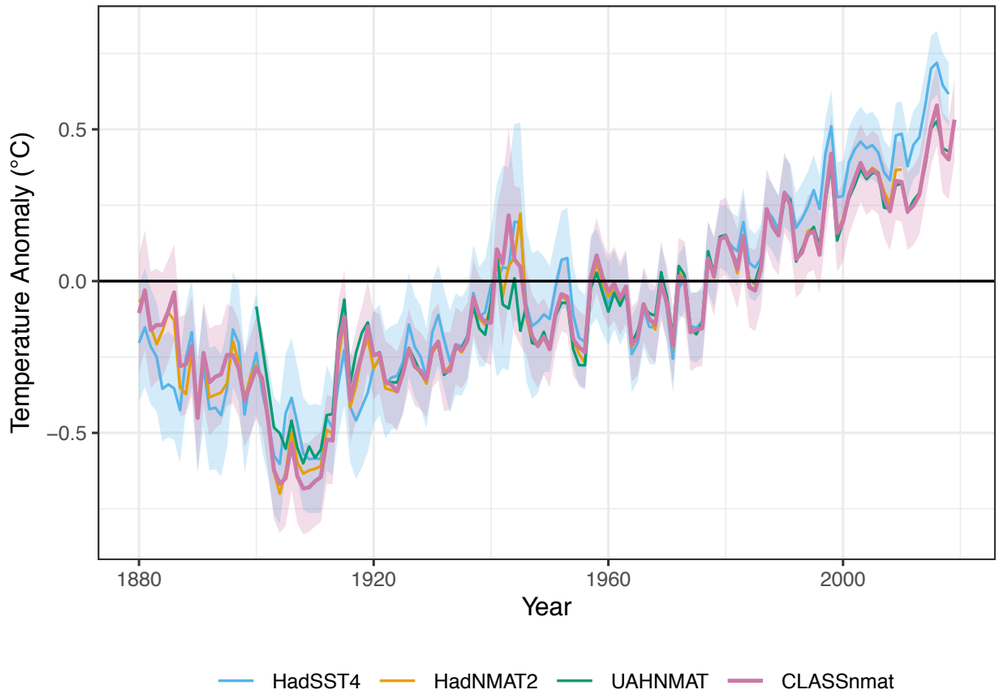
Essential novel datasets for characterising climate change

A new data set (CLASSnmat) has been developed that provides monthly mean, gridded values of Night Marine Air Temperature back to 1880 across global ocean regions. CLASSnmat complements the more widely used sea-surface temperature datasets as an indicator of global temperature change and serves as a reference dataset for the evaluation of reanalysis and modelled data.

The CLASS global upper ocean heat content product (derived from Argo float data) contributed to a new, international review of Earth's energy imbalance. The oceans continue to absorb more than 90% of global warming heat. The analysis will play a central role in informing and advising policy through the Intergovernmental Panel on Climate Change (IPCC) and other channels. NOC has been requested to run a special update of the product to inform a WMO statement on climate.



Global temperature anomalies from new CLASSnmat dataset compared to previous datasets of sea surface and night marine air temperatures

HadSST4	Met Office Hadley Centre sea surface temperature dataset
HadNMAT2	Met Office Hadley Centre and NOC night-time marine air temperature dataset
UAHNMAT	University of Alabama night-time marine air temperature dataset

OCEAN AND CLIMATE PREDICTIVE SYSTEMS DEVELOPMENTS AND IMPACT

Key global model configurations underpinning the UK's capability in ocean prediction for climate change and operational oceanography

CLASS scientists improve the representation of physical processes in the NEMO ocean-ice model and enhance its computational efficiency through NOC's membership of the international NEMO Consortium. We construct rigorously tested global model configurations for UK prediction systems (weather forecasting, including short term ocean "weather" forecasts, seasonal/decadal climate predictions, and century-scale climate projections). These configurations are delivered in collaboration with the Met Office and UK academic research institutions via the Joint Marine Modelling Programme (JMMP).

NEMO's computational efficiency has been significantly enhanced by improving treatment of model grid points that lie at the boundaries of the individual computer processors and large portions of the code have been rewritten to accommodate a new more accurate time-stepping scheme. A major improvement to the physics is the inclusion of a more realistic treatment of sea ice deformation and flow, break up via wave-ice interaction, and surface melt ponds.

The next configuration of NEMO for use in UK forecasting systems is GO8 (Global Ocean configuration #8), developed with the Met Office through JMMP. This has been extensively tested under CLASS and features a new sea ice scheme, SI3; reduced spurious numerical mixing due to inclusion of a more accurate advection scheme; a new equation of state based on latest theory and observations; and we are in the process of adding a new cutting edge ocean surface boundary layer scheme (OSMOSIS). For the subsequent configuration, GO9, we are developing a new approach to modelling overflows of deep water masses through critical sills such as the Denmark Strait and the Greenland-Scotland ridge.

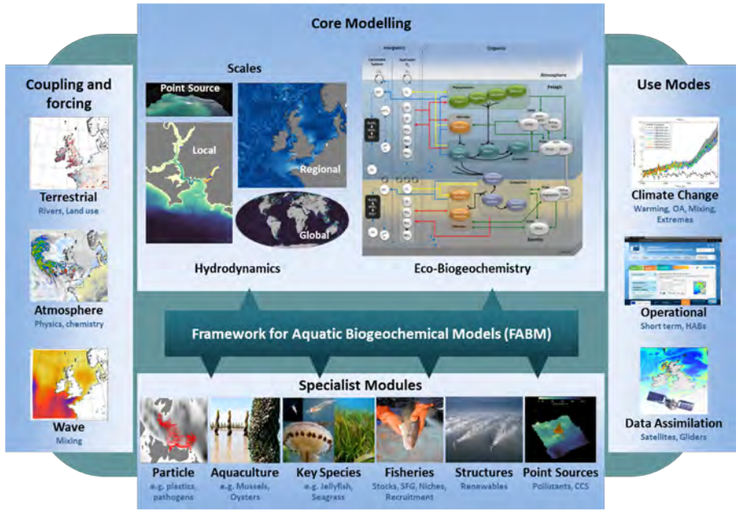
The MEDUSA model, a marine biogeochemistry component used in the global models, has been improved with dynamic C:N stoichiometry which removes potential errors in future C-cycle fluxes that can arise from fixed stoichiometry. The benthic ecosystem is represented more accurately to capture the full seafloor ecosystem from bacteria to fish using BORIS, a benthic biomass model.

Key shelf sea model configurations underpinning the UK's capability in shelf sea prediction for NW European waters and beyond

The Atlantic Margin Model (AMM) vertical coordinate set up has been revised to give better results on shelf slopes where there is very steep topography, (to minimise, for example, horizontal pressure gradient errors). Wetting and drying processes (representing a mobile coastal water line) and improved Baltic boundary conditions have also been incorporated.

The ERSEM ecosystem model code (ERSEM 20.10) has been publicly released, including harmonised formulations, and updated documentation. There are upwards of 280 registered users worldwide. In the AMM7 model we have improved the definition of river inputs and boundary conditions. The flexible coupling of external model systems to ERSEM via FABM is advancing, for example a model suite that uses PyLag particle tracking, ShellSim for aquaculture, embedded in ERSEM with physics driven by FVCOM is being used to examine the impacts and interactions between microplastics and mussel culture.

New functionality has been added to COAsT, a tool for examining kilometric scale regional models. For example, arbitary vertical slices can be selected and the properties (e.g. velocities, transports) of these sections can be plotted. This facilitates the comparison between observations and model simulations in order to assess to model performance.



PML's coupled marine system

ACSIS
North Atlantic Climate System Integrated Study

BORIS
Benthic Organisms Resolved in Size

COAsT
Coastal Ocean Assessment Toolbox

ERSEM
European Regional Seas Ecosystem Model

FABM
Framework for Aquatic Biogeochemical Model (Connects a hydrodynamic model with multiple biogeochemical models)

FVCOM
Finite Volume Community Ocean Model
(Provides 3D simulations of ocean's physical properties)

MEDUSA
Model of Ecosystem Dynamics, nutrient Utilisation, Sequestration and Acidification

NEMO
Nucleus for European Modelling of the Ocean (A modelling framework developed by a European consortium for research and forecasting in ocean and climate sciences)

ORCA
(A series of global ocean configurations used when running some models)

OSMOSIS
Ocean Surface Mixing, Ocean Sub-mesoscale Interaction Study

PRIMAVERA
PRocess-based climate sIMulation: AdVances in high resolution modelling and European climate Risk Assessment (European Union funded project)

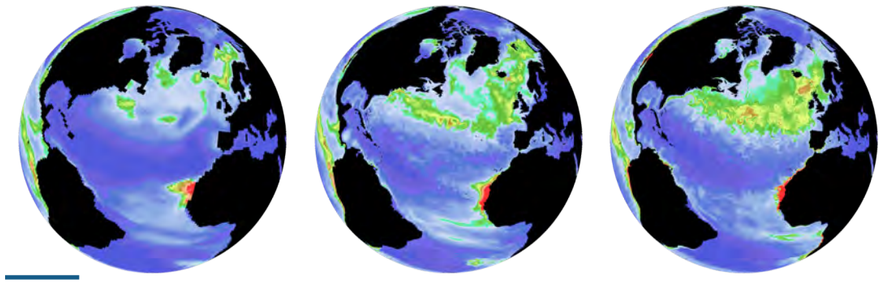
PyLag
A Python Lagrangian particle tracking framework

ShellSIM
Model that simulates shellfish growth and population dynamics

Global and regional simulations to investigate the impacts of climate change on the marine environment

Model simulations provide valuable data in studying the influence of climate change on the marine environment and ecosystems. Understanding potential impacts enables mitigation measures to be put in place and appropriate management of e.g. coastal areas, fisheries and Marine Conservation Zones. Simulations can also be used to test observation strategies, enabling better targeting of resources, or to put limited observations into a longer term context. For example, a relationship observed in the first years of the OSNAP array suggested that the much of the variability of the sub polar meridional overturning circulation was found in the eastern part of the North Atlantic while the western part played a much lesser role. This was also observed in modelling but over a longer time period suggesting this was not just short term feature.

CLASS has completed two coupled model simulations in collaboration with the ACSIS and PRIMAVERA projects and work is now well underway to complete coupled ORCA12-MEDUSA simulations. These simulations will run to the end of this century at increasing resolutions. Analysis of simulations at different resolutions can reveal processes that might not be apparent from only one simulation.



ORCA12-MEDUSA simulations at increasing resolution showing biological production

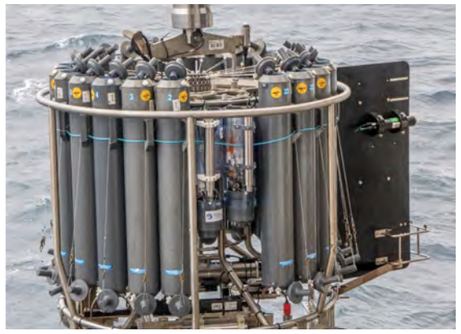
Ocean modelling work does not happen in isolation over the space of a couple of years! The work in CLASS feeds into a vast array of other projects and programmes, however it is also the product of decades of underpinning work.

ENHANCEMENTS IN CHARACTERISING OUR CHANGING OCEAN THROUGH INNOVATION

Chemical and biological sensor development

In situ lab-on-chip sensors for measurement of the ocean carbonate system have been successfully deployed in a range of environments on various platforms. As part of an offshore CO_2 release experiment, total alkalinity (TA) and pH sensors were used on landers and ROVs, while trials in Loch Ness allowed testing on an AUV. The deep ocean capability of the pH sensor was proven during a cruise to the PAP observatory site with several successful deep (~4820m) deployments. Further improvement of the sensors is ongoing with integration of TA and dissolved inorganic carbon (DIC) sensors onto a single device to increase performance and reduce power usage.

Biological sensor development includes RoCSI (Robotic Cartridge Sampling Instrument), an autonomous particle sampler to target microbiology and eDNA, Cytochip, a microcytometer for shallow water work, and Amplitron, an in situ genomic analyser (DNA and RNA detection). RoCSI has been completely redesigned and is undergoing extensive bench testing prior to deployments at the Western Channel Observatory and on an AUV at ~3000m. The benchtop version of Cytochip is operational; unique cytometric profiles have been generated for harmful algal blooms (HABs). The next step is a redesign to improve portability and robustness for in situ deployments.



pH lab on chip sensor mounted on CTD frame during deployment at the PAP site

AutoSub Long Range (ALR) with total Alkalinity and pH lab on chip sensors

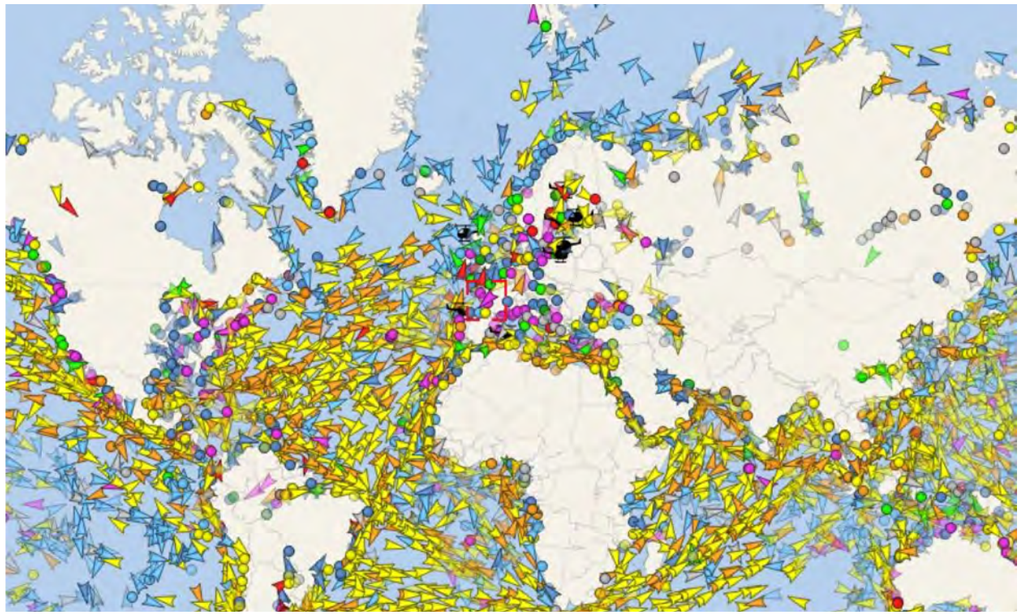
Power and communications

To fully capitalise on sensor technologies and platforms, improved power and communications are vital as these will enable longer uninterrupted time series, fewer site visits and immediate access to data. CLASS is investigating energy harvesting and more efficient data transfer to avoid reliance on increasing numbers of batteries.

A prototype wave energy harvesting system and a supercapacitor storage prototype (for wave and solar energy) have been shown to work in the laboratory and will be tested in the field shortly. Demonstration of CTD sampling driven by wave energy has shown promise but will require adaptive sampling based on power availability.

Data transfer using the Satellite Automatic Information System (S-AIS) allows small bursts of data to be sent from AIS transponders and relayed via satellite at a fraction of the cost of the Iridium network. There are no transmission limits and it can be powered by harvested or renewable energy. However, transmitting VHF signals via satellite is complex; not every message sent is guaranteed to be received. Work is ongoing to investigate transmission success rates and patterns to ensure optimum data transfer.

Supercapacitor energy storage – electronics are being developed to manage the energy store



The AIS (automatic identification system) is an automatic tracking system that uses transceivers on ships, plot shows snapshot of global marine traffic

Novel remote and autonomous platforms

Measurements of air-sea interactions from oceanographic research vessels can be contaminated by the presence of the vessel itself. For example, disruption of wind flow around the vessel can cause turbulent fluxes, and the shadow of the vessel can affect observed scattered light. While modelling allows some correction of these effects, a better solution is to use remotely piloted aircraft systems (RPAS) and autonomous surface vehicles (ASVs) away from the ship.

In this phase of the CLASS project, RPAS and ASVs have been successfully deployed from shore and ship. An acoustic weather station deployed on an ImpYak, a robotic impeller driven kayak, has been used to obtain near surface meteorology, and an Acoustic Doppler Current Profiler (ADCP) mounted through-hull was also used to obtain upper level ocean velocity profiles. Geo-stationary capability of the ImpYak has been proven.

Water landable RPAS have been used to successfully measure upper-boundary-layer winds. The measurements are derived from the full onboard avionics instrumentation which enable accurate determination of velocity, position and altitude. Fieldwork was restricted in 2020 due to Covid-19 but further testing of the systems is already underway including mapping in conjunction with modelling to compare results.

Increasing use of in situ and remote technologies to provide measurements and monitoring of the Atlantic Ocean is vital if we are to fully understand this ecosystem and our impact on it, without also inadvertently impacting it ourselves. Ship-based measurements will always have their place and access to ocean observatories for servicing will be needed. However, in situ and remote technologies can provide measurements over much larger areas and on much longer timescales and in areas that would otherwise be inaccessible due to geography (e.g. under sea ice) or weather conditions.

Impacts of COVID-19

CLASS has of course not been immune to the impacts of Covid-19. The most obvious consequence was the suspension of the National Marine Facilities cruise programme in March 2020. This affected two major CLASS cruises originally scheduled for the summer to carry out operations at Ellett Array (Rockall Trough), the Darwin Mounds and Whittard Canyon Marine Protected Areas (MPA), and the Porcupine Abyssal Plain (PAP). The cruise programme resumed in September 2020 and both expeditions were completed successfully, albeit with reduced numbers of scientists on board and a necessarily reduced scientific programme. The impacts of Covid-19 on the cruise programme are likely to continue for the foreseeable future, with pressure on available ship time affecting CLASS into 2021 and 2022.

Inevitably, the delays to fieldwork and loss of productivity due to laboratory and office closures, will have a knock on effect to the completion of some CLASS deliverables. However, risks to the programme are being closely monitored and the CLASS participants have all worked hard to adapt to the circumstances and minimise disruption to the science programme.

Natural Environment Research Council

National Oceanography Centre

PML Plymouth Marine Laboratory

SAMS Scottish Association for Marine Science

THE MARINE BIOLOGICAL ASSOCIATION

Sea Mammal Research Unit

projects.noc.ac.uk/class